Matrix-type semiconductor package with heat spreader

The invention relates to a matrix-type semiconductor package having a heat spreader.

US 6,541,310 discloses a method for fabricating an encapsulated semiconductor package which includes an embedded heat spreading frame.

US 6,444,498 discloses a method for assembling an encapsulated semiconductor package which includes a heat spreading plate.

These methods are of including a heat spreader in an encapsulated package are complex and inconvenient.

It is one object of the invention to provide a semiconductor package with a more efficient heat spreader and a simpler and more economic method of assembling a package including a heat spreader. This object of the invention is solved by the subject matter of the independent claims. Further improvements arise from the subject matter of the dependent claims.

The semiconductor package according to the invention comprises a semiconductor chip which includes an active surface with a plurality of chip contact areas and a package substrate. The package substrate includes a plurality of first contact areas on its upper surface and a plurality of second contact areas on its bottom surface.

The chip is mounted on the package substrate with its active surface facing the package substrate. A plurality of conducting means provide electrical contact between the chip contact

areas and the first contact areas of the package substrate. The conducting means preferably comprise solder balls or bumps, wire bonds or flexible tape. The space between the active surface of the chip and the package substrate is preferably underfilled with epoxy resin. The external contact means, such as solder balls, are connected to the second contact areas on the bottom of the package substrate to provide electrical contact from the package to, for example, an external circuit board.

The semiconductor package also includes a heat spreading means or heat spreader or heat dissipater or heat slug. The heat spreader comprises a planar area, for example an essentially flat plate, and at least one protrusion, such as protruding bar. The planar area of the heat spreader is attached to the upper surface of the chip and the protrusion of the heat spreader is attached to the upper surface of the package substrate.

The heat spreader preferably comprises a material of good thermal conductivity in order to improve heat removal or dissipation from the chip. Typical materials include metals such as copper or aluminium or their alloys. These have the additional advantage that they are relatively inexpensive and easy to process. Preferably, the surfaces of the heat spreader, including both those facing away from and towards the chip, are black in colour. This again improves the efficiency of the heat dissipation from the package.

Preferably, the heat spreader includes two protrusions which are located on opposite sides of the chip. These protrusions are attached to the package substrate. This has the advantage that the heat spreader is mounted in a stable configuration

and exerts less downwards force onto the chip. This leads to a higher reliability of the package as the delicate contacts between the chip and the package substrate are less likely to be damaged.

Preferably, the two protrusions are provided along the whole length of the two opposing sides of the package substrate. The protrusions or protruding bars preferably have an essentially square or rectangular cross-section. This has the advantage of increasing the stability of the heat spreader. Additionally, the outer surface area of the heat spreader is increased which leads to improved heat dissipation from the package.

The heat spreader according to the invention is also advantageously laterally essentially the same size as the package substrate. This has the effect of maximizing the surface area of the heat spreader further increasing the efficiency of heat dissipation.

Preferably, the package includes two opposing sides which are open and not enclosed by the heat spreader. The package and chip are preferably not encapsulated by epoxy resin or mould material. This has the advantage that the surfaces of the heat spreader are not covered, or partially covered, by mould material. Heat dissipation from the package is therefore advantageously improved and an additional step in the assembly process to remove mould material which has flashed onto the heat spreader during the moulding process is avoided. This has the further advantage that the assembly of the package is simplified and is, therefore, more economic.

The semiconductor package of the invention includes open-ended air tunnels which extend from one side to the opposing side of

the package. The air tunnels are formed between the chip, the heat spreader and the package substrate. These air tunnels have the advantage that heat is more directly removed from the active surface of the chip, particularly as the chip is not completely encapsulated by mould material. More advantageously, a flow of air through the air tunnels is used to further facilitate heat removal from the package.

The heat spreader is preferably attached to the upper surface of the semiconductor chip by adhesive means of high thermal conductivity. This advantageously improves the dissipation of heat from the chip. The heat spreader is attached to the package substrate by non-conductive adhesive means. This advantageously prevents shorting between any conductor tracks or contact areas on the upper surface of the package substrate and the heat spreader.

The adhesive means comprises any adhesive known in the art. For example, the adhesive means comprises a fluid adhesive such as epoxy. This has the advantage that any slight differences in height are compensated for when the heat spreader is attached to the chip and package substrate. Alternatively, the adhesive means comprises adhesive tape. This has the advantage that the adhesive will not spread onto the surrounding areas during the attaching process but remain in the area on which it was originally placed.

The heat spreader according to the invention is advantageously used for any semiconductor package in which the active surface of the chip faces the package substrate, such as Ball-Grid Array or laminate package or Thin and Fine Ball-Grid Array type packages or Multi-Chip Modules. The package substrate comprises, for example, a redistribution board. Preferably, the

chip is mounted to the redistribution board using the flip-chip technique.

The invention also relates to methods of assembling a semiconductor package which includes a heat spreader.

A method comprises the following steps. Firstly a matrix-sized or module heat spreading or dissipating means or heat slug or matrix-sized heat spreading module is provided.

The heat spreading module comprises a plurality of sawing grooves on its upper surface. Preferably the sawing groves are V-shaped and include two orthogonal sets of parallel spaced grooves, one set arranged laterally and the other set arranged longitudinally forming a regular array, such as a square grid array. The spacing between the sawing grooves is approximately the same as that of the desired package size. Preferably, the sawing grooves extend to the outer edges of the upper surface and through the side walls of the matrix-sized heat spreading module. This enables the position of the saw blade to be guided from the outer edge during the singluation process.

The matrix sized heat spreading module further includes a plurality of grooves in its bottom surface. Preferably, these grooves have a rectangular cross-section and are laterally positioned between one set of the sawing grooves on the upper surface of the matrix-sized heat spreader. The bottom surface of the matrix-sized heat spreading module includes protrusions which preferably have a rectangular or square cross-section. These protrusions extend from one side to the opposite side of the matrix-sized heat spreader and are regularly spaced. The spacing between the protrusions is chosen so that when it is mounted on the substrate including a plurality of package

sites the chip is located within the groove in the bottom surface and the protrusions make contact with the substrate between the rows of chips. One of the sets of V-shaped sawing grooves in the upper surface of the heat spreading module is located in the edge of the upper surface and is positioned essentially in the lateral centre of the protrusions.

In the next step of the process, thermally conductive adhesive means is attached to the laterally flat surface of the grooves and non-conductive adhesive means is attached to the protrusions of the bottom surface of the matrix-sized heat spreading module.

A substrate or matrix package substrate or carrier chip module is provided which comprises a matrix of package sites arranged in an array. Each package site includes a semiconductor chip mounted on a package substrate such as a redistribution board. The matrix sized heat spreading module is then positioned on the substrate so that the upper surface of the grooves in the bottom surface of the heat spreading module are positioned on the upper passive surface of the chip and the protrusions are positioned on the package substrates of the substrate between the rows of chips. The adhesive means is then cured by an appropriate curing treatment, such as by heating in an oven.

A plurality of external contact means, such as solder balls, are then attached to the external contact areas located on the bottom surfaces of the plurality of package substrates of the substrate. The individual semiconductor packages are then singulated or split or separated by using the sawing grooves in the upper surface of the heat spreading module to guide the path of the saw blade.

Preferably the chips are mounted in rows and columns in a regular array, such as a square grid array. The spacing and arrangement of the chips on the matrix substrate typically depends on the desired type of chip, mounting method and type of package.

Preferably, the plurality of chips are mounted at each package site of the substrate to a redistribution board using the flip-chip technique. The area between each chip and its redistribution board is advantageously filled with epoxy resin. This protects the delicate contacts between the chip and the redistribution board.

The matrix-sized heat spreader of the invention is suitable for use in a variety of different types of semiconductor package without necessarily changing the dimensions of the heat spreader, if, for example, the matrix of package sites on the substrate is similar and the chip thickness and bump size is essentially the same and the chip fits laterally within the groove. Manufacturing costs and the assembly process are, therefore, further simplified.

Additionally, the heat spreader of the invention is suitable for use in multi-chip modules where a plurality of chips are arranged laterally. In this embodiment, the planar area or flat plate of the heat spreader is preferably attached to a plurality of chips of the multi-chip module.

Advantageously, the invention relates to a method of mounting a matrix-sized heat spreader or heat spreading module or heat slug to a plurality of semiconductor chips mounted on a matrix package or chip carrier or matrix substrate.

The mounting of the matrix-sized heat spreading module on a plurality of chips in a batch-type manner has the advantage that the assembly process is much simpler, faster, and therefore more efficient and economic. The method of the invention has the advantage that a pre-defined matrix-type substrate including the chips may be fabricated using the existing assembling line in the factory. This means that the method according to the invention provides further advantages as an entirely new assembly line is not required.

The direct attachment of the heat spreader to the chip by adhesive with a high thermal conductivity provides an efficient path for the heat transfer from the chip to the heat spreading means. The heat spreader acts as a shelter for the chip so that a moulding process step is not necessarily required, reducing the material costs as well as the process cycle time.

Advantageously, the heat is not only transferred through any mould or encapsulation material reducing the heat transfer path. The surface area of the heat spreader which is exposed to the atmosphere is large, as both the upper surface and side walls of the heat spreader form the outer surface of the semiconductor package. This has the advantage that heat is more efficiently dissipated from the package and the Junction-to-Ambience thermal resistance of the package is lowered. The two open sides of the heat spreader therefore form two open sides to the package. Air is able to flow through the package further improving the heat dissipation from the package. Thus the thermal management and the reliability of the package is improved.

An embodiment of the invention will now be described by way of example with reference to the drawings.

Figure 1 shows a cross-sectional view of a semiconductor package assembled according to the method of the invention,

Figure 2 shows a perspective top view of a matrix-sized heat spreading module according to the invention,

Figure 3 shows the attachment of adhesive to the bottom surface of matrix-sized heat spreading module of Figure 2,

Figure 4 shows the attachment of the matrix-sized heat spreading module of Figure 3 to a substrate containing a plurality of semiconductor chips arranged in a matrix grid array,

Figure 5 shows the singulation of the matrix-sized package of Figure 4 to form a plurality of the semiconductor packages of Figure 1.

Figure 1 shows a flip-chip semiconductor package 1 assembled according to the invention. The package comprises a semiconductor chip 2 mounted by the flip-chip technique to a re-distribution board 4 and a heat spreader 10 which is attached to the upper passive surface of the semiconductor chip 2 and to the upper surface of the re-distribution board 4. The re-distribution board 4 and heat spreader 10 laterally larger than the semiconductor chip 2 and have approximately the same lateral size.

The semiconductor chip 2 includes a plurality of chip contact areas 3 on its active surface and the re-distribution board 4 includes a plurality of contact areas 6 on its upper surface. The semiconductor chip 2 is mounted with its active surface facing the a re-distribution board 4 by microscopic solder balls 5 which provide the electrical contact between the con-

tact areas 3 on the chip 2 and contact areas 6 on the re-distribution board 4. Microscopic is used in this context to describe that the solder balls which are seen with the aid of a light microscope. This type of mounting of the chip 2 to a re-distribution board 4 is commonly known as the flip-chip technique.

The space between the active surface of the chip 2 and the upper surface of the re-distribution board 4 is filled with an insulating epoxy resin 7 so that all of the microscopic solder balls 5 are covered with the resin 7. The re-distribution board 4 also includes conducting tracks on its upper surface and conducting tracks and vias within its thickness (not shown in the figure) which connect the contact areas 6 on its upper surface to the external contact areas 8 on its bottom surface. Macroscopic solder balls 9 are connected to these external contact areas 8 and they provide the electrical connection from the package 1 to an external printed circuit board, which is not shown in the Figure for clarity. Macroscopic is used in this context to describe that the solder balls are visible to the naked eye.

The semiconductor package 1 also includes a heat slug or heat spreading or heat dissipating means or heat spreader 10. The heat spreader 10 comprises a laterally essentially square flat plate 11 which includes two protruding bars 12 which have an essentially rectangular cross-section. The outer vertical surface of each protruding bar 12 is roughly vertically aligned with the outer side surface of the flat plate 11 so that a longitudinal groove 14 with an essentially rectangular cross-section is formed in the lateral centre of the heat spreader 10. The longitudinal groove 14 is more clearly seen in the perspective views of Figures 2 and 3. The lateral distance be-

tween the inner vertical walls of the protruding bars 12 is larger than that of the chip 2 and the height of the groove is slightly larger than the distance of the upper passive surface of the mounted chip 2 above the upper surface of the re-distribution board 4.

The upper outer edges of the heat spreader 10 have a chamfered edge 13 which is a result of the package singulation process which is described later and illustrated in Figure 5. The heat spreader 10 is laterally essentially the same size as the re-distribution board 4 of the package 1.

The heat spreader 10 is attached in its centre by the inner upper surface formed by the groove 14 to the passive upper surface of the chip 2 by means of thermally conducting adhesive 15. The width of the thermally conducting adhesive 15 is slightly greater than the width of the chip but narrower than the width of the groove. The heat spreader 10 is also connected by the bottom surface of the protruding bars 12 to the upper surface of the re-distribution board 4 by non-conductive adhesive 16.

The heat spreader 10 is connected to the re-distribution board 4 on only 2 sides of the package 1 by the protruding bars 12. This is more clearly shown in the perspective views of Figures 2 and 3. The heat spreader 10 is laterally essentially the same size as the redistribution board 4 of the package. Therefore, the protruding bars 12 are attached to the redistribution board 4 from the front side to the back side of the re-distribution board 4 and the package 1 as it is seen in Figure 1. The spaces 17 formed between the inner vertical walls of the protruding bars 12 of the heat spreader 10 and the chip 2 therefore form open-ended tunnels 17 from the front side to

the back side of the package 1. The front and back side walls of the heat spreader 10 and therefore the package 1 are therefore open and the left and right side walls are solid.

Figure 2 shows a perspective view of the matrix-sized heat spreader 19. The matrix-sized heat spreading module 19 is attached to a substrate 20 including a plurality of flip-chip mounted semiconductor chips arranged in a matrix grid array in the method of the invention shown in Figures 3 to 5.

Figure 2 shows that the matrix-sized heat spreading module 19 comprises an approximately square metal sheet 23 which includes 2 sets of V-shaped sawing grooves 18 and 24 in its upper surface. One set of 3 parallel grooves 24 are positioned laterally, the second set of 4 parallel grooves 18 are positioned longitudinally with respect to the outer dimensions of the metal sheet 23. The sawing grooves 18 and 24 are arranged to form a square grid pattern in the upper surface of the metal sheet 23 and approximately correspond to the 3 by 3 matrix of package sites 21 of the substrate 20. The spacing of the grooves 18 and 24 approximately corresponds to the outer dimensions of the semiconductor package 1. The sawing grooves 18 and 24 extend across the upper surface and through the side walls of the heat spreading module 19.

The metal sheet 23 of the matrix-sized heat spreading module 19 also includes three grooves 14 of a laterally rectangular cross-section located in its bottom surface. These grooves 14 are positioned essentially parallel to each other and in the longitudinal direction of the metal sheet 23. The grooves 14 are laterally positioned so that they lie approximately centrally between the V-shaped grooves 18 on the opposite surface of the metal sheet 23 of the matrix-sized heat spreading mod-

ule 19. The bottom surface of the metal sheet 23 therefore includes four protruding bars 25 of approximately rectangular cross-section. The V-shaped grooves 18 are therefore located in the edge of the upper surface of the matrix-sized heat spreading module 19 and are located in approximately the lateral centre of the four protruding bars 25.

Figure 3 shows the attachment of the adhesive to the matrix-sized heat spreading module 19 in the first step of the method to form the package 1 according to the invention. An adhesive 15 with particularly good thermal conduction properties is attached to the lateral surface of the each groove 14. An electrically non-conducting adhesive 16 is attached to the lateral surface of the longitudinal protruding bars 25.

Figure 4 shows the substrate 20 which includes package sites 21 for nine semiconductor chips 2 arranged in a 3 by 3 matrix grid array. The chips 2 and package sites 21 are arranged in rows and columns. The area of each package site 21 is denoted by demarcation lines 22 arranged in a square grid array whose dimensions and orientation are approximately the same as the square grid array formed by the V-shaped grooves 18 and 24 of the matrix-sized heat spreader 19. The substrate 20 includes a semiconductor chip 2 mounted in the centre of each package site 21 using a known flip-chip technique for matrix-sized substrates or carrier chip modules.

Referring to Figure 1 and Figure 4, each chip 2 is therefore mounted by means of a plurality of microscopic solder balls 5 between the contact areas 3 of the chip 2 and contact areas 6 of a re-distribution board 4. The area between each chip 2 and the distribution board 4 of each package site 21 is underfilled by epoxy resin 7 so that the space between the active

surface of the chip 2 and the microscopic balls 5 are covered by epoxy resin 7. The epoxy 7 is then cured by heating in an oven.

The matrix-sized heat spreading module 19 is then mounted on the substrate 20 which includes the matrix of chips 2 mounted in the package sites 21. The matrix-sized heat spreading module 19 is positioned so that the protruding bars 25 are positioned approximately centrally between the rows of mounted chips so that the longitudinal V-shaped grooves 18 and 24 in the upper surface of the heat spreading module 19 are located approximately above the package demarcation lines 22 of the substrate 20.

In this orientation, the thermally conductive adhesive 15 is attached to the upper passive surface of the chips 2 and the insulating adhesive 16 is attached to the upper surface of the re-distribution board 4. The adhesives are then cured so provide a secure connection between the matrix-sized heat spreading module 19 and the chips 2 and redistribution boards 4 of the substrate 20. The solder balls 9 are then attached to the external contact areas 8 on the bottom side of the re-distribution board 4 of each package site 21.

Figure 5 shows the singulation of the individual packages 1 from the matrix package formed by the matrix-sized heat spreading module 19 and the substrate 20 containing nine packages 1 arranged in a 3 by 3 array. The V-shaped groves 18 and 24 in the matrix-sized heat spreading module 19 provide a guide for the saw blade.

The semiconductor packages 1 are then be tested and packaged for transportation to the customer. The semiconductor packages 1 are be mounted on an external printed circuit board.